Ocular Ultrasound

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KEYWORDS

• Ultrasonography • POCUS • Vision loss • Retinal diseases • Eye diseases
• Papilledema • Emergency medicine

KEY POINTS

- Point-of-care ultrasound (POCUS) can evaluate pathology in the anterior chamber, posterior chamber, and retrobulbar structures of the eye.
- When performing an ocular POCUS examination, the operator should anchor their hand to reduce direct pressure on the globe.
- Use of high gain and ocular kinetics can increase sensitivity for pathologies, such as vitreous detachment.

Video content accompanies this article at http://www.emed.theclinics.com.

INTRODUCTION

Approximately 1% of emergency department (ED) visits in the United States involve diagnoses related to eye complaints.[1] Studies have shown that ocular point-of-care ultrasound (POCUS) can expedite the diagnosis of vision-threatening pathology and aid in ED plan of care and disposition of patients.[2] Indications for ocular POCUS include, but are not limited to, acute vision loss, orbital trauma, and/or evaluation of intraocular pressure.[2] This article will discuss the ultrasound anatomy of the eye, procedural approach to ocular POCUS, and how to identify various emergent pathologies on ocular POCUS.

ANATOMY

Ocular anatomy can be separated into anatomy of the globe and surrounding muscular, fatty, and bony structures. The globe contains 2 separate chambers, the anterior chamber and the posterior chamber. The anterior chamber comprises the cornea, iris, lens, and ciliary body. This chamber is filled with a water-like substance

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called aqueous humor. On ultrasound, aqueous humor appears anechoic. In contrast, the lens and iris are hyperechoic (Fig. 1). The posterior chamber consists of the vitreous humor bounded by the choroid, retina, and optic nerve. Similar to the aqueous humor, the vitreous humor will appear anechoic on ultrasound. However, in older patients, nonpathologic faint vitreous opacities may be present.[3] The surrounding choroid and retina are hyperechoic. Finally, the optic nerve can be visualized posterior to the globe and is typically hypoechoic. The optic nerve sheath runs along the outer portion of the nerve and is typically isoechoic to hyperechoic when compared to the surrounding anatomy (see Fig. 1).[3]

PROCEDURAL APPROACH

How to Scan

Ultrasound is generally considered safe for the eye. Ocular POCUS typically uses the high-frequency linear probe, which is preferred for the identification of superficial structures. One should also use the as low as reasonably achievable principle when performing this study. If the ultrasound machine has an ocular setting, it can be used to provide safe mechanical index and a thermal index of less than 1.[4] This helps to protect the patient's eye from unnecessary damage.[4] However, most physicians believe that ocular POCUS is contraindicated when one suspects the diagnosis of globe rupture, as the pressure of the probe can potentially worsen the insult by causing extrusion of the intraocular contents.[5]

To begin the examination, the patient should lie either flat, in the supine position or with the head of the bed elevated at approximately 45°. The patient is instructed to close their eyes. Traditionally a clear adhesive film (or Tegaderm) is placed over the patient's eyelid. However, new data suggest that this can cause image degradation, and instead a copious amount of sterile ultrasound gel can be placed directly on to the patient's closed eye lid.[6]

If opting to use an adhesive film, and the patient has false eyelashes or makeup, the patient should be advised that these products may be removed or affected by the adhesive film. Caution should be exercised while applying the film to prevent trapping air bubbles between the film and the skin, as this will compromise the visualization of structures on ultrasound.

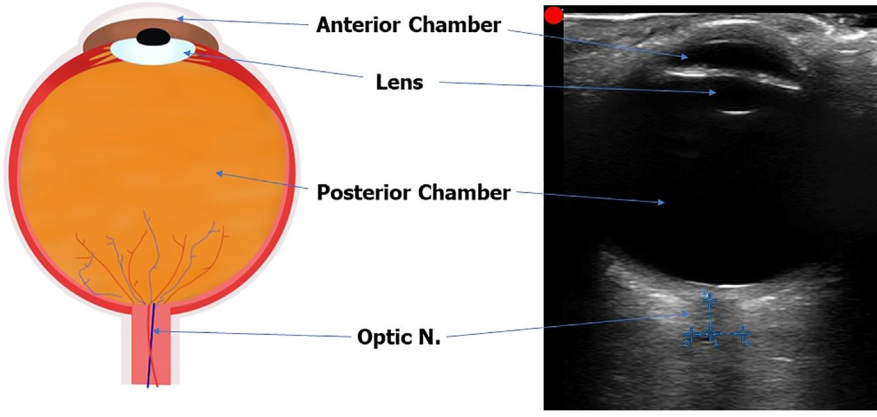

Fig. 1. General Ocular Anatomy. Notice the anechoic appearance of the anterior and posterior chambers compared to the hyperechoic lens and iris. The optic nerve is the hypoechoic linear structure posterior to the globe.

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After a copious amount of sterile ultrasound gel has been placed over the patient's eyelid, the sonographer's wrist is anchored on the patient's maxilla (or bridge of the nose) to minimize the pressure of the probe on the eye. If there is concern for facial trauma, injury, or instability, then the sonographer's elbow can be anchored on the patient's stretcher to minimize the pressure of the probe on the eye (**Fig. 2**).

To obtain a sagittal view of the eye, the probe is placed with the indicator pointing toward the top of the patient's head. The probe is then fanned from left to right while the patient looks straight ahead, and then have the patient look to the extremes of gaze, slowly looking from left to right (see **Fig. 2**) (Video 1).

To obtain a transverse view of the eye, the probe is placed with the indicator pointing toward the patient's right side, regardless of the eye being scanned. The probe is then fanned from up to down while the patient looks straight ahead, and then have the patient look to the extremes of gaze, slowly looking up and down (see **Fig. 2**).

PATHOLOGY

Anterior Chamber

Lens dislocation

Lens dislocation occurs when the lens is displaced posteriorly into the vitreous humor or posterior chamber. This typically occurs post-surgery or as the result of trauma, but it can also be secondary to a genetic predisposition (eg, connective tissue disorder).[7] Patients may present with symptoms of vision loss, double vision, eye pain, headache, or visualization of the lens. On POCUS, a complete lens dislocation will appear as a hyperechoic annular structure that is usually mobile in the vitreous humor or posterior chamber (**Fig. 3**) (Video 2).[8] Treatment is typically intraocular lens exchange by an ophthalmologist. On POCUS, a partial lens dislocation may show the lens in the normal position while the patient is supine but show that it is detached when the patient is sitting upright, or it may show one side detached. If there is a strong clinical suspicion, the emergency physician (EP) can scan the eye with the patient in both the supine and upright positions.

Fig. 2. Approach to Ocular Examination. This image shows probe and patient positioning for the sagittal and transverse views with the option of using a clear adhesive dressing.

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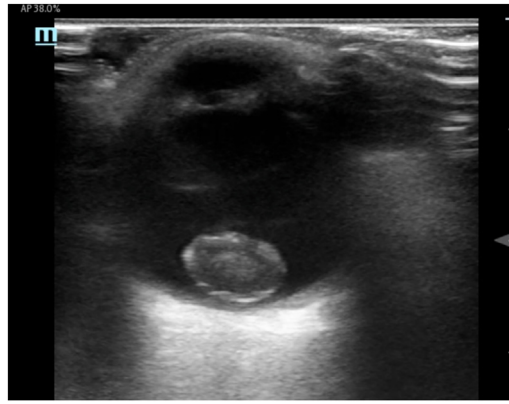

Fig. 3. Lens Dislocation. This image shows the hyperechoic lens at the bottom of the posterior chamber. (*Photo courtesy* of Dr. Timothy Beau Stokes, MD.)

Ocular light response

Pupillary light reflex, also known as consensual light response, is a brainstem reflex. It occurs when a light is shined into one eye, and the contralateral pupil constricts in response. POCUS performed pupillary examination has been shown to have substantial agreement with clinical examination based on Kappa coefficient (0.74).[9] It can also help in situations where clinical examination is not feasible, such as in periorbital edema.[9] The pupillary light reflex can be demonstrated with POCUS by placing the probe transversely just below the eye on the zygomatic bone, at a 45°angle toward the eye to maximize visualization of the pupil.[10] A light is shined into the patient's contralateral pupil, while ensuring that the patient does not directly look at the light. On POCUS, the constriction of the pupil can be visualized (**Fig. 4**) (Video 3).[10] The diameter of the constricted pupil can be measured and compared to that of the contralateral eye.

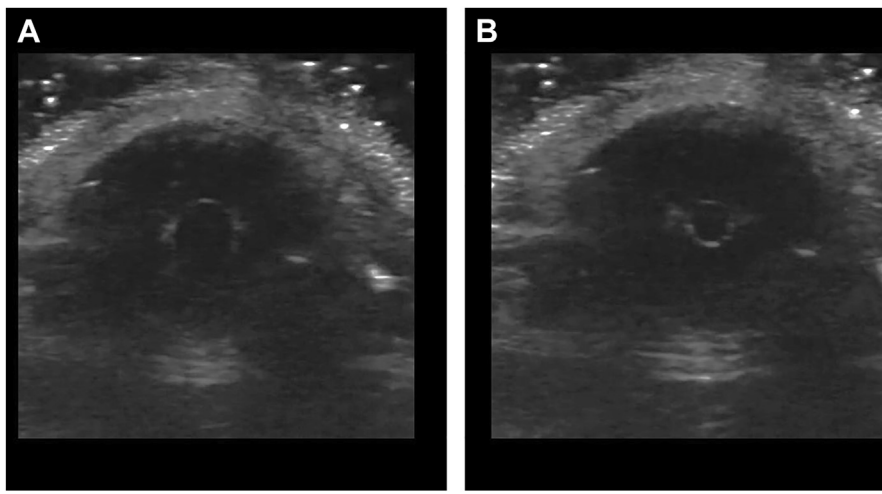

Fig. 4. Ocular Light Response. This image shows the ocular light response. In A the pupil is dilated and in B the pupil is constricted.

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Posterior Chamber

Retinal detachment

Retinal detachment (RD) is a rare but serious pathology that should be included in the differential diagnosis for patients presenting with painless vision loss. RD occurs when the neurosensory retina detaches from the retinal pigment epithelium and is often described by patients as a curtain-like visual field deficit. There are 3 types of RD: rhegmatogenous, tractional, and exudative.[11] Rhegmatogenous RD is the most common and occurs when a tear in the retina allows vitreous humor to leak into the subretinal space separating the neurosensory retina from the retinal pigment epithelium.[12]

POCUS has a sensitivity of 94% and specificity of 96% in the detection of RDs.[13] On POCUS, RD is identifiable as a thick hyperechoic band-like structure protruding into the vitreous space (**Fig. 5**) (Video 4).[14] Since the retina is a continuation of the optic nerve, the RD can be seen tethered to the optic nerve without crossing over the nerve, which can be better visualized with the patient moving their eye from side to side.[14] A dynamic ocular ultrasound, as described above in the procedural approach, can help to identify the location of the tethered portion of the detachment. This helps to distinguish an RD from a posterior vitreous detachment (PVD).

When an RD is visualized, it can be helpful to determine whether the detachment involves the macula. The macula is located laterally to the optic nerve. If the RD is only in the periphery and has not reached the macula, this is referred to as a macular sparing RD. This subcategory of RD is considered emergent as the patient's vision is more likely to be recoverable.[15] If an RD is seen on POCUS, or there is high concern based on the history, emergent discussion with an ophthalmologist is recommended.[14]

Vitreous detachment

PVD is a pathology that should also be considered in patients presenting to the ED with painless vision loss. The classic symptoms can range from hazy or black floaters to partial vision loss.[14] PVD occurs when the vitreous humor detaches from the internal lining of the retina. On POCUS, PVD appears as a serpentine hyperechoic structure floating in the vitreous chamber (see **Fig. 5**) (Video 5).[14] In contrast to an RD, a PVD is not tethered to the optic nerve and is generally thinner, more limber, and less hyperechoic. These qualities can make visualizing a PVD on POCUS challenging. Therefore, a high gain setting can increase the sensitivity of the study (**Fig. 6**).[16] Kinetic echography, or motion

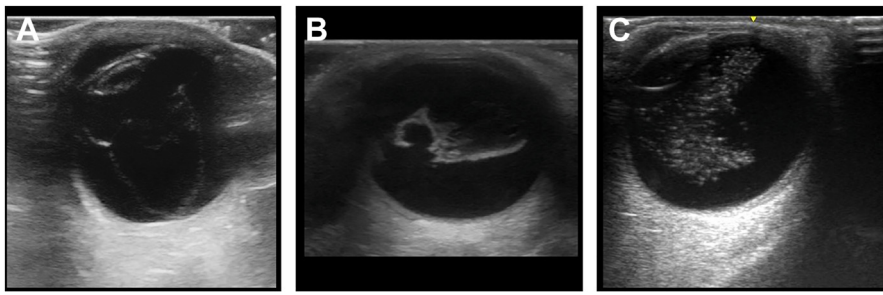

Fig. 5. Posterior Chamber Pathology. This image shows 3 different types of posterior chamber pathology. (*A*) depicts medial and lateral retinal detachments tethered to the optic nerve. (*B*) depicts a vitreous detachment, notice a hyperechoic serpentine structure that transverses across the optic nerve and is not tethered to the optic nerve. (*C*) depicts a vitreous hemorrhage, notice the hyperechoic contents in the vitreous body. (Photo courtesy of Dr. Samuel Hsu, MD.)

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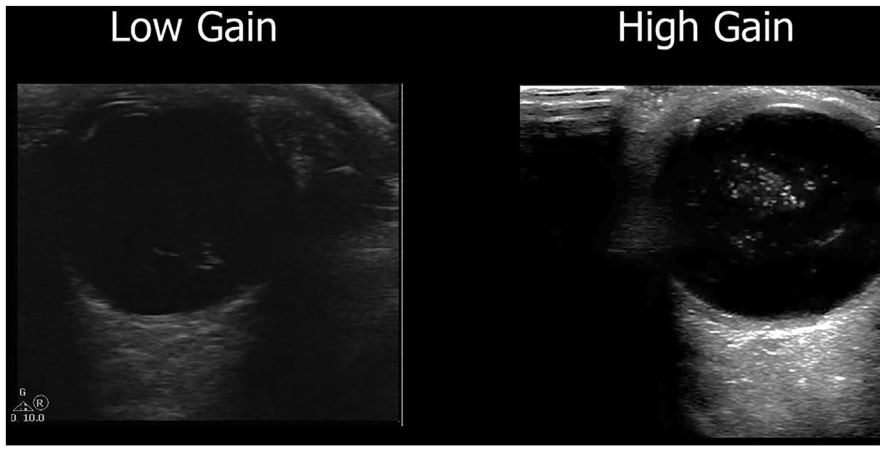

Fig. 6. High Gain Setting. This figure shows how a high gain can increase sensitivity of an ocular POCUS study.

of the patient's eye during the scan, can also aid in detection. Overall, POCUS has a sensitivity of 67% and specificity of 89% in the diagnosis of PVDs.[17]

Vitreous hemorrhage

Vitreous hemorrhage is bleeding due to rupture of the vessels of the posterior chamber. This rupture of blood vessels can occur spontaneously or from trauma.[17] PVDs and RDs can both be associated with a vitreous hemorrhage. On fundoscopy, a vitreous hemorrhage will have a red hazy appearance overlying the retina. On POCUS, a vitreous hemorrhage appears as mobile echogenic foci or collections floating in the vitreous body (see **Fig. 5**) (Video 6).[17] Similar to the PVD, high gain setting and kinetic echography will aid in the detection of a vitreous hemorrhage on POCUS.[16] When kinetic echography is used, the hemorrhage can be seen swirling in the vitreous body. This swirling is sometimes referred to as a "washing machine" appearance.[18] Overall, POCUS has a sensitivity of 90% and specificity of 92% in the diagnosis of vitreous hemorrhage.[17]

Asteroid hyalosis

Asteroid hyalosis (AH) is often referred to as a vitreous hemorrhage mimic. This pathology is a benign condition in which small opaque objects float in the vitreous body (**Fig. 7**). AH is associated with increasing age and typically seen in patients older than 60 years.[19,20] AH can occur unilaterally or bilaterally, rarely affects visual acuity and typically does not require intervention.[20] On POCUS, the appearance of AH involves more discrete and widespread hyperechoic foci in the vitreous body as compared to a vitreous hemorrhage.[20] It is commonly described as having a "stars in a night sky" appearance.[18] Furthermore, a dilated eye examination with ophthalmology can help distinguish the 2 pathologies.

Foreign body

Ocular injuries are a common chief complaint of patients presenting to the ED. Of these injuries, intraocular foreign bodies can account for up to 41% of open globe injuries.[21] On POCUS, foreign bodies will typically appear hyperechoic with shadowing, with the shape dependent upon the foreign body. Glass and metallic foreign bodies may exhibit an obvious reverberation artifact, while materials like dry wood may

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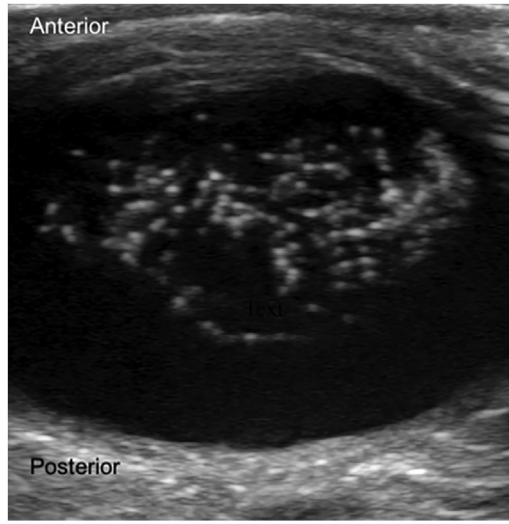

Fig. 7. Asteroid hyalosis. (Kevin Kucharski, Jonathan Watson, Jonathan E. Davis, Elderly Woman With Painless Visual Loss, Annals of Emergency Medicine, 80 (6), 2022, 507-547, https://doi.org/10.1016/j.annemergmed.2022.05.035.)

have a more subtle reverberation artifact.[22] As with soft tissue POCUS, air within the globe will appear as hyperechoic foci with dirty shadowing posterior to it.

Retrobulbar Structures

Increased intracranial pressure

Elevated intracranial pressure can result from various disease processes. When intracranial pressures are elevated, the optic nerve sheath dilates, and the optic disc begins to elevate into the vitreous body. Thus, POCUS can be used to aid in the diagnosis of intracranial hypertension through 2 methods: assessing the optic nerve sheath diameter (ONSD) and evaluating for optic disc elevation (ODE).[23] Abnormally high ODE and ONSD values should raise concern for increased intracranial pressures.

For standardization, the ONSD diameter is traditionally measured 3 mm posterior to the globe.[24,25] The ONSD is then measured at this level transversely outer wall to outer wall of the optic nerve sheath (**Fig. 8**). When measuring the ONSD, it is important to distinguish the optic nerve sheath from the optic nerve. The optic nerve is the hypoechoic to anechoic structure exiting the posterior aspect of the globe. The optic nerve sheath is the isoechoic to hyperechoic structure outlining the nerve. A diameter less than 5 mm in adults and less than 4 mm in children is considered normal.[23,26] However, the accepted upper limit for abnormal does vary by study. One meta-analysis reported using a threshold of 5.0–5.3 mm is associated with a sensitivity of 91% and specificity of 82%.[23] Threshold values of 5.5–5.8 mm yield a sensitivity and specificity of 97% and 89%, respectively.[23] In patients with traumatic brain injuries, ocular ultrasound has a sensitivity of 97% and specificity of 86% in diagnosing increased intracranial pressure.[23]

Papilledema can be evaluated on POCUS by focusing on the optic disk or where the optic nerve inserts into the eye. In the setting of increased intracranial pressures, the optic disk can protrude into the vitreous body, causing papilledema.[27] The distance of protrusion into the vitreous body is called ODE.[27] Some studies have used greater than 0.6 mm as the cutoff for an abnormal ODE (see **Fig. 8**).[27–29]

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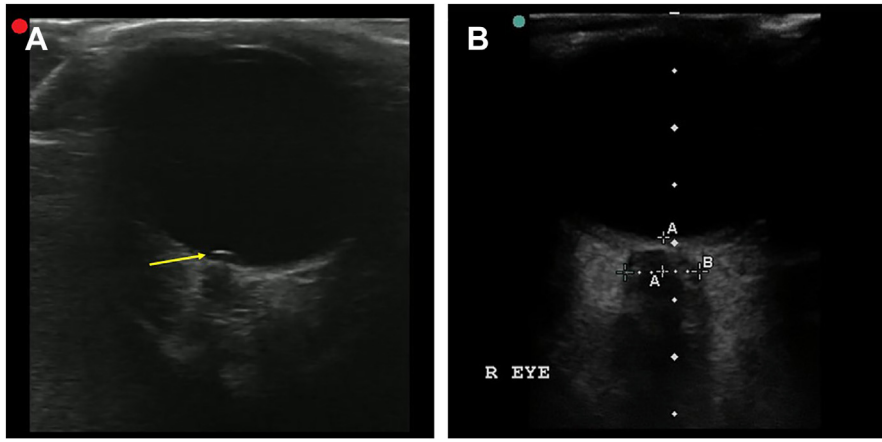

Fig. 8. Signs of Elevated Intracranial Pressure. (*A*) arrow points to prominent protrusion of the optic disk into the vitreous body due to papilledema. (*B*) depicts an enlarged ONSD measurement in a patient with optic nerve sheath edema.

Central retinal artery occlusion

Central retinal artery occlusion (CRAO) is an ocular emergency that presents as an acute, painless monocular vision loss.[30] It is often associated with atherosclerotic comorbidities such as hypertension, hyperlipidemia, and diabetes. A thromboembolism is the most common cause of CRAO.[30] On ocular POCUS, the retrobulbar spot sign can be observed in some patients presenting with CRAO, serving as a negative prognostic factor associated with secondary retinal ischemia.[31] The retrobulbar spot sign appears as a small hyperechoic density just below the retina within the optic nerve sheath (**Fig. 9**).[31] The absence of color Doppler may also be noted in the area of the central retinal artery, near the optic nerve sheath. Treatment for CRAO includes orbital massage, vasodilators, and agents that reduce intraocular pressure.[30]

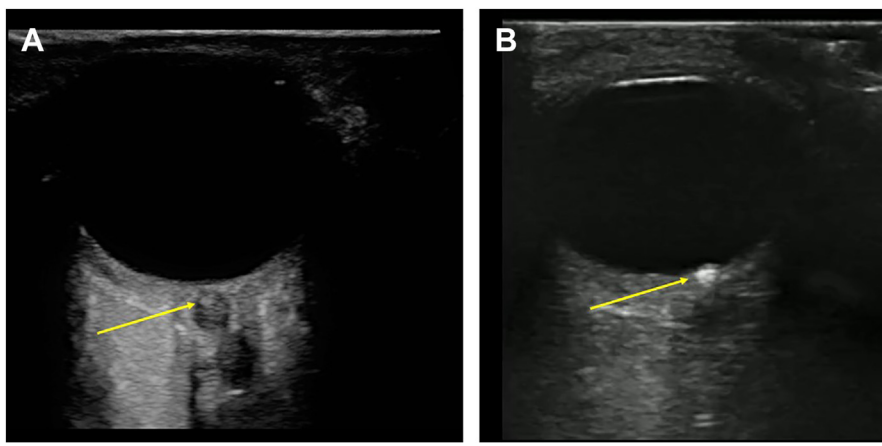

Fig. 9. Retrobulbar Pathology. This image depicts the difference between CRAO and ODD. (*A*) depicts CRAO, notice the small hyperechoic density below the retina within the optic nerve sheath. (*B*) depicts ODD, notice the large hyperechoic density on the top of the retina, within the vitreous humor.

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Optic disc drusen

Optic disc drusen is a calcified proteinaceous lesion that is congenital and grows onto the optic nerve.[32] It is typically benign but can have pathologic complications, such as peripheral visual field defects.[32] It can also be associated with other pathologic disorders that affect the retina. On POCUS, optic nerve drusen will appear as a large hyperechoic density on top of the retina within the vitreous humor or posterior chamber (see **Fig. 9**) (Video 7).[32] There is no definitive treatment for optic nerve drusen.

Retrobulbar hematoma

Retrobulbar hematoma is an ocular emergency that presents as an acute painful monocular vision loss.[33] It is a collection of blood that accumulates in the retrobulbar space. Most commonly, it occurs secondary to trauma and can present with proptosis and increased intraocular pressure on physical examination.[33] On POCUS, there will be hyperechoic (acute) or hypoechoic (subacute) densities in the retrobulbar space outside of the globe and increased ONSD (**Fig. 10**). The "guitar pick sign," which is a cone-like deformity of the posterior globe, may also be seen on POCUS.[34,35] Treatment is immediate decompression of the orbit with a lateral canthotomy and cantholysis.[33]

Globe Rupture

Globe rupture occurs when there is a traumatic disruption of the integrity of the ocular membranes. Concern for globe rupture is a contraindication for ocular ultrasound because the pressure of the probe can worsen this injury.[5] For this reason, there are fewer studies focusing on the diagnostic utility of ultrasound for globe rupture. However, there are key features recognizable on ultrasound that can raise concern for globe rupture. On POCUS, globe rupture will show the loss of the normal contours of the globe, a flattened or collapsed anterior chamber and vitreous debris or opacities (see **Fig. 10**) (Video 8).[36] Other associated findings may include vitreous hemorrhage, RDs or tears, and choroidal detachments.[37]

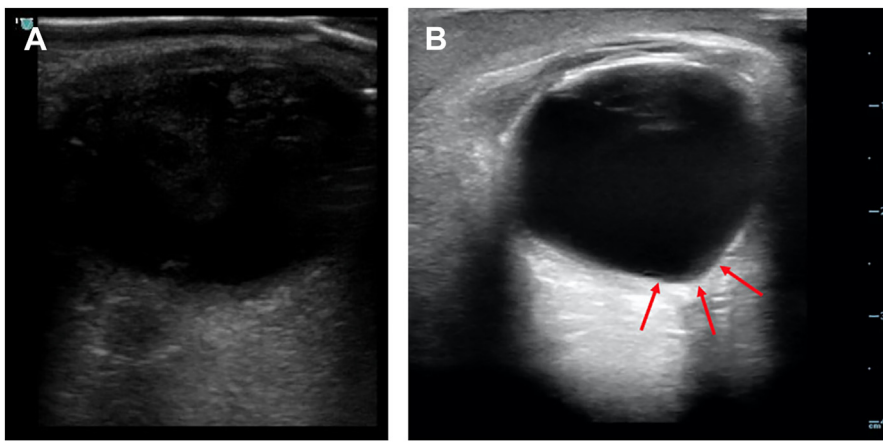

Fig. 10. Ocular Trauma. (*A*) This image shows signs of a globe rupture. Globe rupture photo Image credit: Resa E Lewiss, MD. (*B*) This image shows signs of retrobulbar hematoma. (*Figure adapted from* Reopelle K, Haines, L. Point of care identification of retrobulbar hematoma. V J Emerg Med. 2020; 21: 100867. DOI:10.1016/j.visj.2020.100867)

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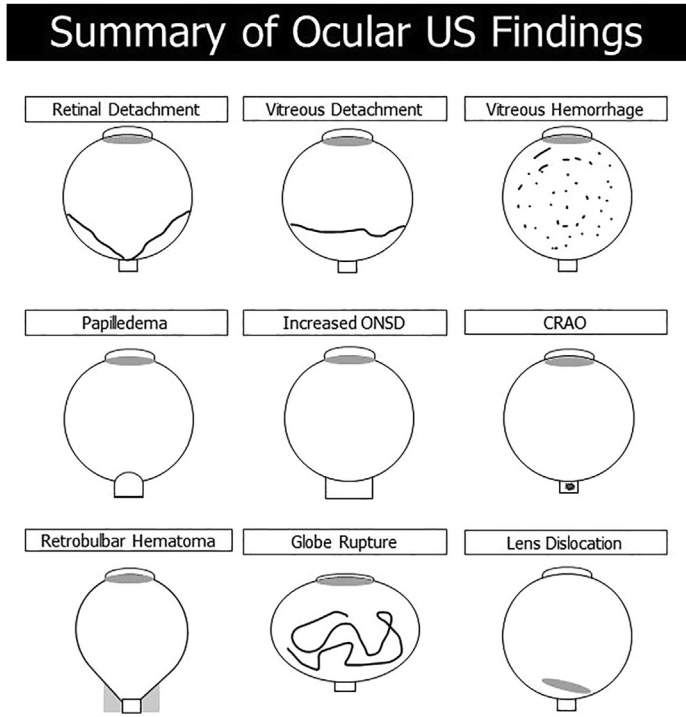

Fig. 11. Ocular Pathology Summary. This image shows a summary of ocular POCUS findings.

SUMMARY

Point-of-care ocular ultrasound is an integral tool for the astute EP to improve diagnosis and care of patients with ocular emergencies. Knowledge of safe techniques for ocular POCUS is essential to caring for these patients. Utilizing POCUS can aid in diagnosing conditions such as retinal and vitreous detachments, traumatic eye injuries, and CRAO (Fig. 11). Integrating POCUS into a clinical ocular examination will provide a comprehensive assessment of patients presenting to the ED with ocular complaints.

CLINICS CARE POINTS

- Many patients will present to the ED for ocular-related concerns.
- Ocular examination should be performed with a linear probe in the ocular preset.
- For patients who present with ocular trauma, the EP can evaluate for signs of lens dislocation, foreign body, hemorrhage, and increased intracranial pressure.
- For patients who present with sudden vision loss, the EP can evaluate for signs of vitreous and RD, vitreous hemorrhage, and CRAO.
- The combination of optic nerve sheath edema and disc elevation are associated with increased intracranial pressure.

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DISCLOSURE

The authors have nothing to disclose.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.emc.2024.05.009.

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